1493345 PROVISIONAL SPECIFICATION
3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

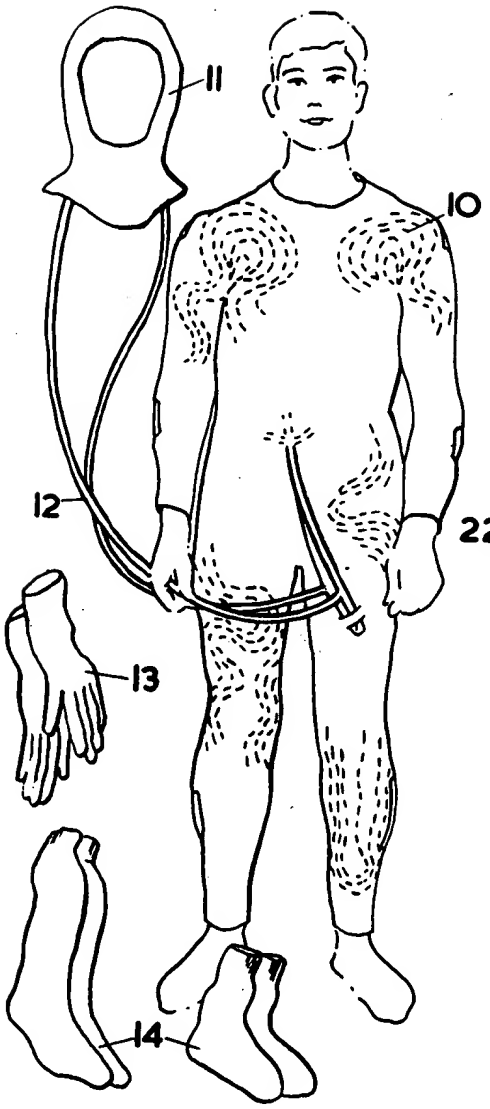

FIG. 1.

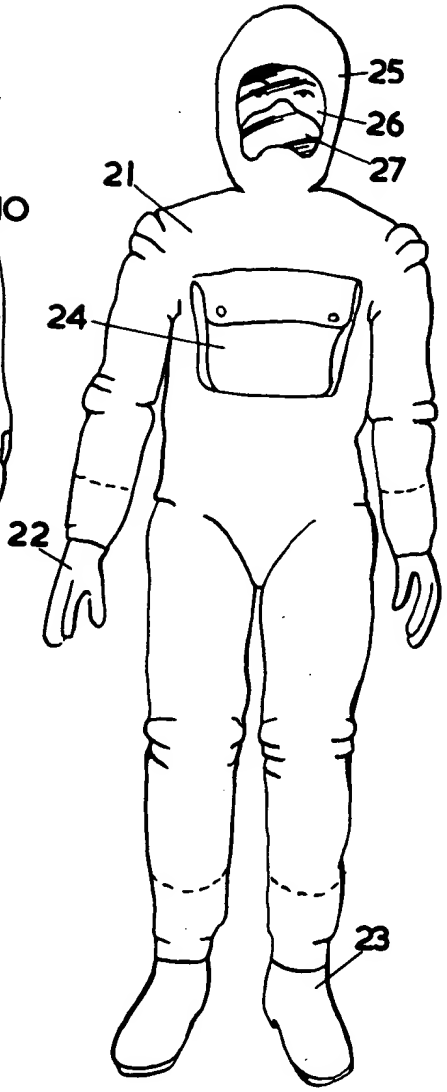

FIG. 2.

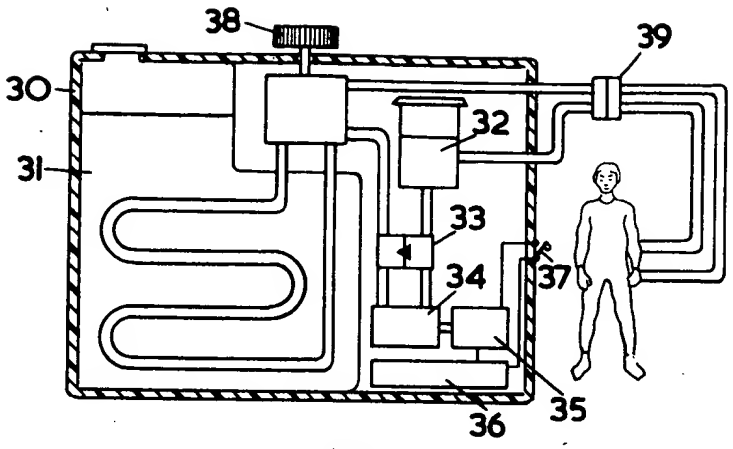

FIG. 3.

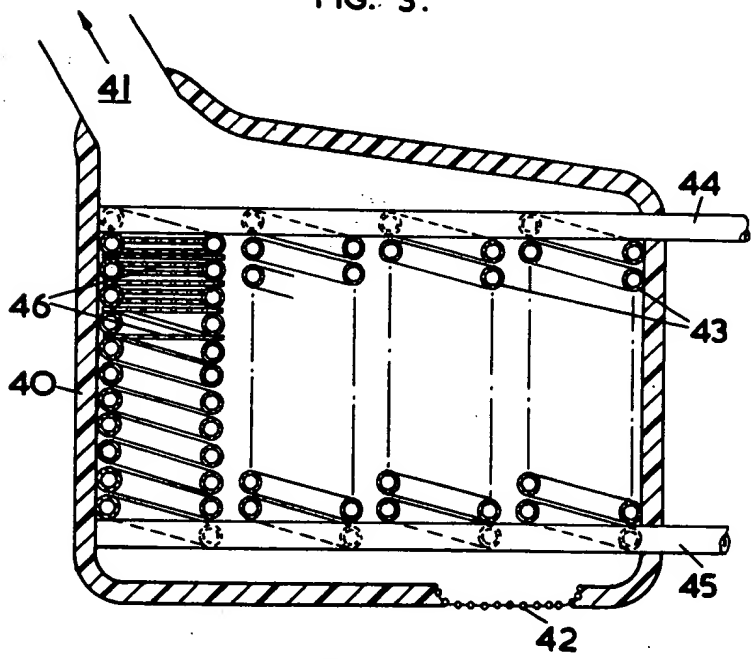

FIG. 4.

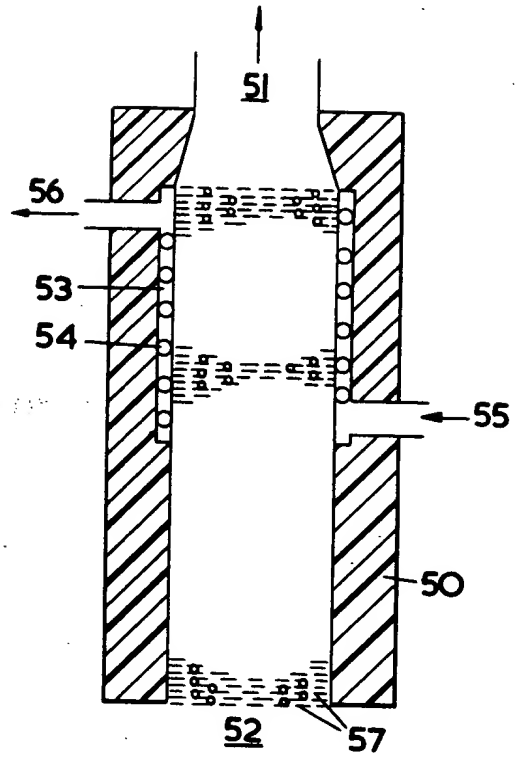

FIG. 5.

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(54) IMPROVEMENTS IN OR RELATING TO INHOSPITABLE ENVIRONMENT PROTECTIVE APPARATUS

(71) I, SECRETARY OF STATE FOR DEFENCE, London, do hereby declare the invention, for which I pray that a patent be granted to me and the method by which it is to be performed, to be particularly described in and by the following statement:

The present invention relates to protective apparatus, particularly to breathing air conditioning apparatus and to clothing for protecting the wearer from a hot, and possibly humid, environment.

In industries employing plant which operates at high temperature considerable saving may be available if the maintenance of the plant can be carried out before it is cooled to ambient temperature, or to temperatures humanly bearable, especially if cooling the plant takes a long time. In these situations the atmosphere to the maintenance area, though hot and possibly toxic and dangerous to contact or breathe usually contains oxygen.

The present invention provides a protective apparatus wherewith the wearer can work for a period of time in such an environment.

According to one aspect of the present invention a breathing air heat exchanger comprises a heat exchange element in a respirator duct for both inhalate and exhalate, the heat exchange element including a heat exchange fluid duct adapted for connection to a supply of heat exchange fluid, whereby in use, with the fluid duct connected to a fluid supply the heat exchange element can be cooled by exhalate and heat exchange fluid in consort and then act to cool inhalate.

Preferably the breathing air heat exchanger has heat conductive gauzes in contact with heat conductive walled tubing whereby in use the tubing conducts cooling liquid from the portable cooler to extract heat from the gauzes. Preferably the heat conductive walled tubing and the gauzes are metal.

According to a feature of the invention the breathing air heat exchanger may communicate with an oro-nasal face mask and a filter may be provided in the exchanger for restricting the ingress of toxic or unpleasant substances in the environment. As the internal volume of the filter and exchanger combined would have to be small enough to permit the escape of exhalate the filter is as far as possible arranged to assist in the cooling as well. The exchanger may also be arranged to be portable.

According to another aspect of the invention a breathing air conditioning apparatus may comprise a breathing air heat exchanger and a portable cooler hydraulically coupled thereto.

According to a feature of the said another aspect of the invention the cooler may comprise a reservoir for water, a heat exchanger surrounded by the reservoir and adapted for the throughput of cooling liquid a pump and electric motor operably connected thereto, and a battery for driving the pump, the whole being in a container with low thermal conductivity walling. The battery may be rechargeable and the cooler may also have a proportioning valve, manual or thermostatic, for controlling in use the flow or the temperature of the water. The mode of preparation of such a cooler, when the reservoir is charged with water, may be to pass a coolant through the heat exchanger from an external supply at a temperature sufficiently low at least to freeze the water, and to charge the battery Then when connected to the breathing air heat exchanger, the proportioning valve, if provided, set, and the pump switched on, cooled liquid will be passed from the cooler heat exchanger through the breathing air heat exchanger and back to the cooler heat exchanger until the ice has melted. The

cooler may also include an alarm for warning when only a short period of cooling remains.

A changing unit for this cooler may comprise a reservoir for coolant and a circulatory system, cooling means for cooling the coolant to below 0°C, and a battery charger.

Another suitable portable cooler is described in UK Patent Specification 1,376,604.

The cooler may be carried by means of a shoulder strap, or slung on the wearer's back. It may be mounted on a waistcoat adapted for the purpose as can also the breathing air heat exchanger, the waistcoat being worn inside or outside an outer garment dependent on whether control of the cooler is required during use, or perhaps whether automatic temperature sensitive control of the cooler is provided. In another embodiment the conditioning apparatus is mounted in chest pockets of the outer garment. In this embodiment the shoulders of the outer garment may have an additional lining to obviate reduction of protection brought about by weight of the cooler etc.

The outer garment assembly is usually fabricated of a multi-layer material. One such material has three layers, an outer waterproof layer of neoprene impregnated nylon, a middle layer of polyurethane foam 3-10mm thick, and an inner layer of smooth knitted nylon. Another such material has an outer layer of a synthetic fibre fabric, several alternate intermediate layers of a fabric gauze and a metallised plastics sheet, and an inner layer of a smooth knitted nylon. The assembly normally includes outer gloves made of similar material and long inner fabric gloves. The outer gloves are preferably of the mitten type with separate thumb and forefingers. A separate helmet may be provided made of material similar to that of the rest of the outer garment but having a transparent face covering portion arranged in use to be spaced from the skin of the user. Such a helmet may have a wide skirt for overlapping the shoulders of the wearer sufficiently to prevent ingress of environmental atmosphere. Preferably however the helmet is one piece with the rest of the outer garment, which may then have a slide fastener extending from the top of the head down the back to the base of the spine, the fastener being of the type which upon closure seals against passage of fluid therethrough. The outer garment is usually arranged to extend to the ankles of the wearer. Adequate protection for his feet may be obtained with several pairs of socks overlapping the suit, and boots perhaps with an insulating insole. All seams in the outer garment assembly may advantageously be proofed to prevent leakage therethrough, either with a proofing compound or an adhesive tape.

According to a further aspect of the invention protective apparatus may include an inner garment adapted for cooling by the portable cooler.

Preferably the inner garment is arranged to cover the torso, arms to the wrists and legs to the ankles of the wearer and includes a bonnet portion adapted to cover the sides, back and top of the head. The bonnet portion may be integral with the rest, otherwise they are preferably arranged to overlap in use. The inner garment may be of the type described in UK Patent Specification 1 115 414.

A protective apparatus in accordance with the present invention will now be described by way of example with reference to the drawings accompanying the provisional specification of which:

Fig 1 shows an inner garment assembly,

Fig 2 shows an outer garment assembly,

Fig 3 is a schematic diagram of a cooler, cooler,

Fig 4 is a diagrammatic cross-sectional view of one type of breathing air heat exchanger, and

Fig 5 is a diagrammatic view of another type of heat exchanger.

As shown in Fig 1 the inner garment assembly comprises a liquid cooled suit 10 for covering the torso, arms, legs and feet of the wearer, and a liquid cooled bonnet 11 communicating with the suit 10 via tubes 12. The inner suit is of the type described in UK Patent Specification 1 115 414 in which flexible pipes are located on a garment in an extended circuitous configuration. The inner garment assembly also includes inner gloves 13 and socks 14.

The outer garment assembly shown in Fig 2 comprises an outer overall 21, outer gloves 22 and boots 23. A chest pocket 24 on the front of the overall 21 is provided for the cooler and the breathing air heat exchanger and connections, not shown, to breathing air tubes and the liquid systems are within the pocket. The overall 21 is made of a three layer sandwich, the outer layer being neoprene impregnated nylon and waterproof, the middle layer being polyurethane foam 5 mm thick, and the inner layer being smooth knitted nylon. The three layers are stuck together. From the chest pockets 24 over the shoulder the outer garment has a lining not shown, to reduce the loss of protection otherwise brought about by tension of the garment over the wearer's shoulders. A helmet 25 is integral with the overall 21. A gas seal type slide fastener, not shown, extends from the top of the helmet 25 down to the base of the spine at the back of the over-

all. The helmet 25 has a visor 26 of stiff but non-rigid transparent plastics material able to withstand temperatures up to at least 80°C. Within the visor 26 is an oro-nasal mask 27 and a breathing tube (not shown) connects this with the breathing air heat exchanger.

The cooler shown in Fig 3 comprises an insulated case 30 having a heat exchanger compartment 31 and also containing a reservoir 32, a non-return valve 33, a pump 34, an electric motor 35 and a rechargeable battery 36. A switch 37, a temperature control 38, and a water inlet and outlet connector 39 protrude through the case 30. The cooler is slung in the pocket 24 of the garment 21.

In use of the cooler the compartment 31 contains ice and the reservoir 32 water. With the connector 39 connected to whatever is to be cooled and the switch 37 ON, the pump 34 drives water from the reservoir 32 to the valve 33. This valve controls the amount of water passed through the cooler 31 and the amount which by-passes the cooler in the valve. Water from the valve 33, by-passed or from the cooler, is then pumped through the connector 39.

Such a cooler will operate for a limited time dependent on the temperature gradient. A convenient recharging unit (not shown) comprises a battery charger and a deep freezer with a reservoir of liquid coolant at say −15°C. With the connector 39 connected to this reservoir and the battery 36 to the charger, the coolant can be pumped through the compartment 31 until the water therein is again frozen, and the battery recharged.

One such cooler whose compartment 31 contains 2.2 kg of water measures 30 cm × 10 cm × 29 cm and weighs 4.7 kg when charged. It employs a rechargeable nickel/cadmium battery and can give 350 watts of cooling for 45 minutes.

The breathing air heat exchanger is illustrated in Fig 4 and has an insulating case 40 which is adapted to communicate with the oro-nasal mask at 41 and is open to the outside at 42. The case contains a plurality of copper cooling coils 43 associated with water inlet and outlet tubes 44 and 45 respectively. Discs of metal gauze 46 extend across the coils 43. The case is mounted in the pocket 24 of the outer garment 21.

The alternative breathing air heat exchanger shown in Fig 5 has a cylindrical insulating case 50 somewhat thicker than the case 40 in Fig 4. One end of the cylinder communicates at 51 with the oro-nasal mask 27. The other end of the cylinder is open to the environment at 52. The upper half of the cylinder is lined with a water jacket 53 containing a helical swirl wire 54 to fully distribute the flow of coolant, there being a water inlet and outlet 55 and 56 respectively to the jacket. The cylinder is packed with discs 57 of metal gauze. The gauzes 57 in the bottom half of the cylinder can be replaced by a filter.

This exchanger may be arranged for attachment to the helmet, or for mounting in the pocket 24.

It can be seen that both of the breathing air heat exchangers are regenerative and water cooled in operation. Cooling of the gauze discs 46 or 57 is accomplished during breathing out partly by the user's exhalate and partly by the water in the coils 43 or the jacket 53. The discs and to some extent the cooling system then remove heat from the air being inspired.

An exchanger of the type shown in Fig 4, to be used with a portable cooler, and operating in an ambient air temperature of 73°C dry bulb and 68°C wet bulb and with a water inlet temperature of 11°C and a water flow of 870 ccs/min cooled the breathing air to 47°C dry bulb and 35° wet. Its water outlet temperature was 17°C. An exchanger of the type shown in Fig 5 operating in the same ambient conditions with the same water inlet temperature and water flow rate cooled the breathing air to 56°C dry bulb and 50°C wet bulb and its water outlet temperature was 15°C. In addition its resistance to breathing was the higher.

The suit assembly is donned, the liquid cooled suit 10 first with the helmet 11. The socks 14 and inner gloves 13 are then donned, the gloves passing well up the arm and overlapping the liquid cooled suit sleeves. The outer garment is then climbed into, the necessary connections being made between the liquid cooled suit, the oro-nasal mask 27, and the pipework in the pocket 24, before fastening the slide fastener. The boots 23 are donned and the overall fastened around them. The breathing air heat exchanger (Fig 4) is mounted in the pocket 24 and with the necessary water and air connections made, cold water is pumped through the suit 10 and the exchanger before the cooler (Fig 3) is stowed in the pocket 24 and connected into the circuit. The gloves 22 are then put on and sealed over the sleeves of the suit 21. Just before entering the hot environment the wearer switches on the cooler and checks that it is working.

A wearer of the suit can perform at least some coarse mechanical operations such as operate levers, handles etc and cleaning operations in an environment of up to about 70°C dry bulb, 60°C wet bulb for half to three quarters of an hour before he has to emerge.

WHAT I CLAIM IS:—

1. A breathing air heat exchanger comprising a heat exchange element in a respirator duct for both inhalate and exhalate, the heat exchange element including a heat exchange fluid duct adapted for connection to a supply of heat exchange fluid, whereby in use, with the fluid duct connected to a fluid supply, the heat exchange element can be cooled by exhalate and heat exchange fluid in consort and then act to cool inhalate.

2. A breathing air heat exchanger as claimed in Claim 1 and having heat conductive gauzes in contact with heat conductive walled tubing whereby, in use, the tubing conducts cooling liquid from the portable cooler to extract heat from the gauzes.

3. A breathing air heat exchanger as claimed in Claim 2 wherein the heat conductive walled tubing is metal.

4. A breathing air heat exchanger as claimed in Claim 2 or Claim 3 and wherein the heat conductive gauze is metal.

5. A breathing air heat exchanger as claimed in any one of Claims 1 to 4 which is portable.

6. A breathing air heat exchanger as claimed in any one of Claims 1 to 5 which is adapted to communicate with an oronasal mask whereby exhalate is directed, in use, to and through the gauges.

7. A breathing air heat exchanger as claimed in any one of the preceding claims and having a filter for restricting the ingress of toxic or unpleasant substances in the environment.

8. A breathing air conditioning apparatus comprising a heat exchanger as claimed in any one of the preceding claims and a portable cooler hydraulically coupled therewith.

9. A breathing air conditioning apparatus as claimed in Claim 8 and wherein the cooler comprises a reservoir for water, a heat exchanger surrounded by the reservoir adapted for the throughput of cooling liquid, a pump and electric motor operably connected thereto, and a battery for driving the pump, the whole of the cooler being in a container with low thermal conductivity walling.

10. A breathing air conditioning apparatus as claimed in Claim 9 and wherein the cooler has a proportioning valve, manual or thermostatic, for controlling in use the flow or temperature of the liquid.

11. A breathing air conditioning apparatus as claimed in Claim 8 and wherein the cooler is as claimed in any claim of UK Patent Specification 1,376,604.

12. A breathing air conditioning apparatus as claimed in any one of Claims 8 to 11 and wherein the cooler includes an alarm for warning when only a short period of cooling remains.

13. A protective apparatus comprising a breathing air heat exchanger as claimed in any one of claims 1 to 7 or a breathing air conditioning apparatus as claimed in any one of claims 8 to 12 and including a waistcoat to carry the apparatus, the waistcoat being worn inside or outside an outer garment.

14. A protective apparatus comprising apparatus as claimed in any one of the Claims 1 to 13 and an outer garment.

15. A protective apparatus as claimed in Claim 14 and wherein the outer garment has a chest pocket in which the breathing air heat exchanger is mounted.

16. A protective apparatus as claimed in Claim 14 or 15 and wherein the outer garment has shoulders with an additional lining to reduce loss of protection otherwise brought about by weight of the cooler etc.

17. A protective apparatus as claimed in any one of Claims 14 to 16 wherein the outer garment is fabricated of multi-layer material.

18. A protective apparatus as claimed in Claim 17 and wherein the material has three layers, an outer waterproof layer of neoprene impregnated nylon, a middle layer of polyurethane foam 3-10mm thick and an inner layer of smooth knitted nylon.

19. A protective apparatus as claimed in claim 17 and wherein the material has an outer layer of a synthetic fibre fabric, several alternate intermediate layers of a fabric gauze and a metallised plastics sheet, and an inner layer of a smooth knitted nylon.

20. A protective apparatus as claimed in any one of Claims 14 to 19 and wherein the outer garment comprises an assembly including outer gloves and long fabric inner gloves.

21. A protective apparatus as claimed in any one of Claims 14 to 20 and wherein the outer garment assembly includes a separate helmet having a transparent face covering portion arranged in use to be spaced from the skin of the user, and a wide skirt for overlapping the shoulders of the wearer sufficiently to prevent ingress of environmental atmosphere.

22. A protective apparatus as claimed in any one of Claims 14 to 20 and wherein the outer garment assembly includes a helmet integral with the member for covering a torso and arms and has a slide fastener extending from the top of the head down the back to the base of the spine, the fastener being of the type which upon closure seals against passage of fluid therethrough.

23. A protective apparatus as claimed in any one of Claims 14 to 22 including an inner garment adapted for cooling by the portable cooler.

24. A protective apparatus as claimed in Claim 23 and wherein the inner garment is preferably arranged to cover the torso, arms to the wrists, and legs to the ankles of the wearer and includes a bonnet portion adapted to cover the sides, back and top of the head.

25. A protective apparatus as claimed in Claim 23 and wherein the inner garment is of the type claimed in any claim of UK Patent Specification 1 115 414.

26. A breathing air heat exchanger substantially as hereinbefore described with reference to Figure 4 of the drawings accompanying the Provisional Specification.

27. A breathing air heat exchanger substantially as hereinbefore described with reference to Figure 5 of the drawings accompanying the Provisional Specification.

28. A protective apparatus comprising apparatus as claimed in any one of Claims 1 to 13 and an outer garment substantially as hereinbefore described with reference to Figure 2 of the accompanying Provisional Specification.

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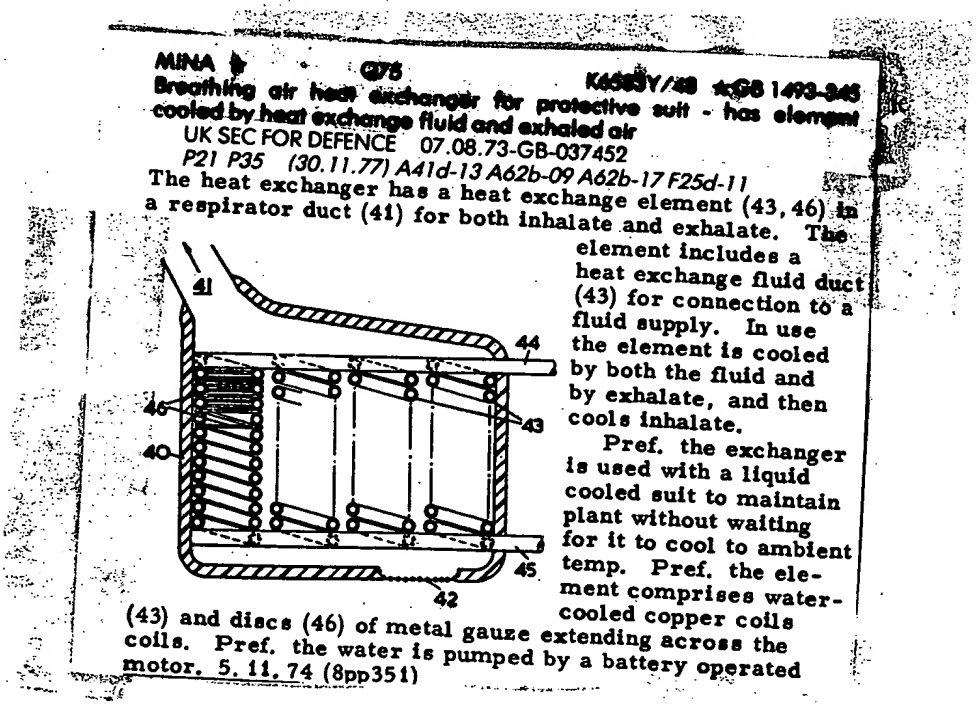

MINA Q75
Breathing air heat exchanger for protective suit - has element cooled by heat exchange fluid and exhaled air
UK SEC FOR DEFENCE 07.08.73-GB-037452
P21 P35 (30.11.77) A41d-13 A62b-09 A62b-17 F25d-11
The heat exchanger has a heat exchange element (43, 46) in a respirator duct (41) for both inhalate and exhalate. The element includes a heat exchange fluid duct (43) for connection to a fluid supply. In use the element is cooled by both the fluid and by exhalate, and then cools inhalate.

Pref. the exchanger is used with a liquid cooled suit to maintain plant without waiting for it to cool to ambient temp. Pref. the element comprises water-cooled copper coils (43) and discs (46) of metal gauze extending across the coils. Pref. the water is pumped by a battery operated motor. 5.11.74 (8pp351)